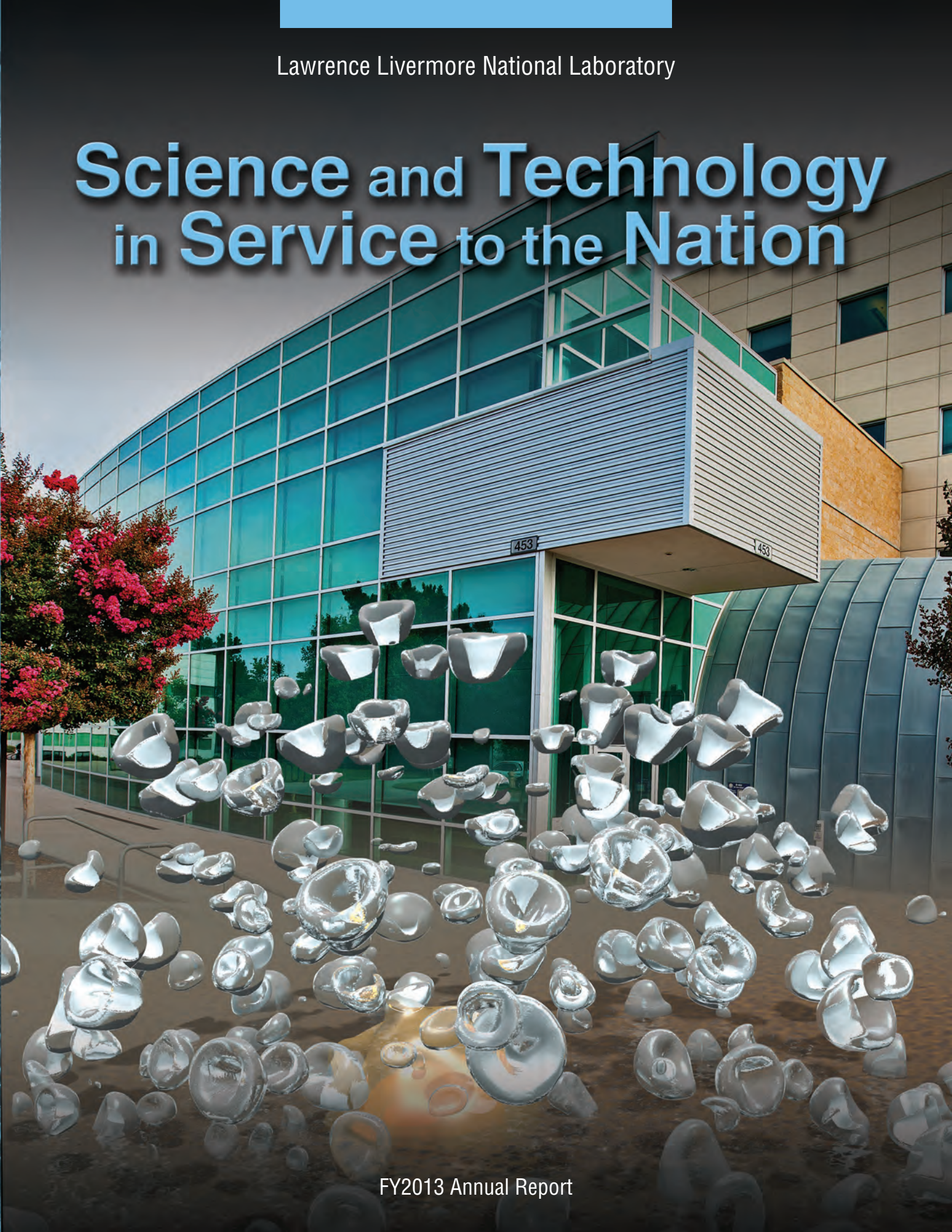
Lawrence Livermore National Laboratory

Science and Technology in Service to the Nation



FY2013 Annual Report

About the Laboratory:

Lawrence Livermore National Laboratory (LLNL) was founded in 1952 to enhance the security of the United States by advancing nuclear weapons science and technology. With a talented and dedicated workforce and world-class research capabilities, the Laboratory continues a tradition of science and technology innovation—anticipating, developing, and delivering solutions for the nation's most challenging problems.

The Laboratory is managed by Lawrence Livermore National Security, LLC (LLNS) for the National Nuclear Security Administration (NNSA), a semi-autonomous agency within the U.S. Department of Energy (DOE). LLNS is a limited liability company managed by Bechtel National, Inc., the University of California, BWX Technologies, Inc., and URS Energy & Construction, Inc. Battelle Memorial Institute also participates in LLNS as a teaming subcontractor. Cutting-edge science is enhanced through the expertise of the University of California and its ten campuses and LLNS' affiliation with the Texas A&M University system.

About the Cover:

LLNL's fiscal year (FY) 2013 *Annual Report* cover features a record-setting simulation showing the collapse of a cloud of bubbles. The simulation, performed on LLNL's Sequoia supercomputer, won the Gordon Bell Prize in 2013. The unique phenomena observed have applications ranging from treating kidney stones and cancer to improving the efficiency of high-pressure fuel injectors. A panoramic view of the Terascale Simulation Facility provides the backdrop.

Lawrence Livermore National Laboratory

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Annual Report

What's Inside FY2013

Continuing a Tradition of Excellence

Our FY2013 *Annual Report* features this year's scientific and technical accomplishments at Lawrence Livermore National Laboratory (LLNL). Mission-directed research at Livermore is focused on difficult challenges in national security, environmental sustainability, and economic competitiveness. We continue LLNL's tradition of excellence, pushing at the frontiers of science and technology to develop innovative solutions with the goal of making the nation—and the world—safer and more secure.

Leadership in high-performance computing is a hallmark of LLNL and an area with numerous successes in FY2013. A key event was the Sequoia supercomputer's transition to classified operations as a user facility for the three Department of Energy National Nuclear Security Administration (DOE NNSA) laboratories—Livermore, Los Alamos, and Sandia. The machine has demonstrated remarkable capabilities in record-breaking unclassified simulations, such as the 2013 Gordon Bell Prize–winning calculation (depicted on the cover). Sequoia now supports the Laboratory's defining mission for NNSA: to sustain a safe, secure, and effective nuclear deterrent for the nation. A smaller version of Sequoia, Vulcan, is meeting the needs of other Laboratory programs.

Coupled with experiments, supercomputer simulations are providing unprecedented capabilities to study physical processes inside nuclear weapons and, more generally, the detailed behavior of complex systems.

Acting LLNS President and LLNL Director Bret Knapp and LLNS Board of Governors Chairman Norman Pattiz.

We have greatly enhanced our capabilities to evaluate the condition of the stockpile as part of the annual assessment process, resolve arising issues, and carry out life-extension programs. High-fidelity simulations combined with experiments at the National Ignition Facility are providing a better understanding of nuclear weapons physics and enabling key advances toward achieving fusion ignition and energy gain. In addition, the Laboratory has demonstrated remarkable success in integrating simulations, experiments, and systems engineering to rapidly design and prototype advanced conventional munitions for the Department of Defense.

We combine our unique capabilities, wide-ranging expertise, and multidisciplinary approach to problem solving to address broader national security needs. Livermore's Forensic Science Center is one of the nation's two laboratories accredited to perform tests for the Organisation for the Prohibition of Chemical Weapons, which was awarded a Nobel Peace Prize this year for its extensive efforts to eliminate chemical weapons. LLNL researchers are helping the Department of Homeland Security to protect commercial aviation against terrorism, aiding Japan in responding to the disaster at Fukushima, and uncovering evidence of human activities on the Earth's climate. In addition, we contribute in many ways to U.S. energy security, and we collaborate with academia to make important advances in science. Through the Livermore Valley Open Campus, our capabilities are being shared with U.S. industry to increase economic competitiveness and promote regional development.

Noteworthy events this year, in addition to our programmatic achievements, significantly affected the Laboratory. We addressed challenges associated with the federal budget sequester and the government shutdown. Nearly 400 employees chose to participate in a voluntary separation program, conducted to right-size the Laboratory for the future. We thank them for their years of dedicated service to the nation. The senior management team has also undergone changes—most notably Parney Albright stepped down as Laboratory director in October 2013. We are especially grateful to him for his leadership during a time of significant change and his energetic efforts to improve the work environment for employees.

LLNL's principal asset continues to be its outstanding workforce—remarkable individuals and highly motivated teams focused on mission delivery and demonstrating programmatic and operational excellence in the national interest. As our *Annual Report* highlights, Laboratory operations in support of our mission-directed research are conducted with great attention to safety, security, and environmental sustainability.

To address ever-evolving national security threats, we must take full advantage of exciting scientific and technical opportunities. With its focus on mission-directed research, Livermore will build on its tradition of innovation and its record of scientific and technical excellence to find solutions to critical national needs. We will rise to future challenges, working diligently as an efficient, effective team—within the Laboratory and across the nuclear security enterprise—to meet our vital mission objectives.

Nuclear Deterrence

Ensuring the safety, security, reliability, and effectiveness of the enduring stockpile

LLNL's foremost responsibility is to ensure the safety, security, reliability, and effectiveness of the nation's nuclear arsenal. The knowledge gained through experiments, theory, and simulations is applied to assess the condition of stockpile weapons and to develop and certify needed modifications with confidence in the absence of nuclear tests.

Annual Stockpile Assessment

In FY2013, LLNL increased rigor and quality in Cycle 18 of the annual stockpile assessment. As part of the overall process, the nuclear design laboratories (Livermore and Los Alamos) each conducted a comprehensive peer review of the other's designed weapons. Laboratory scientists continue to improve the baseline weapons-physics simulation codes that support the annual assessments and certification of weapons. Ongoing experimental programs provided data that enabled marked improvements in the predictive capability of weapons physics models for simulating high-explosives performance and the dynamic properties of materials.

Life-Extension Programs

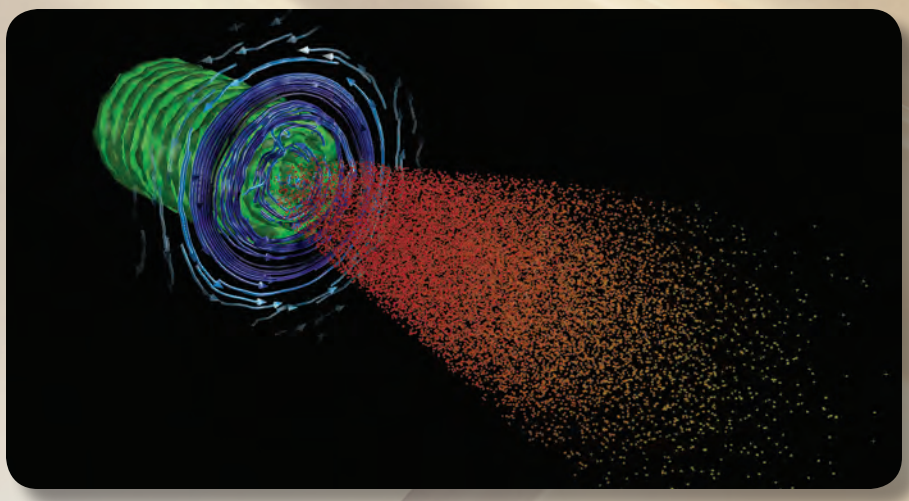
NNSA and the Department of Defense are engaged in an option selection, detailed design, and costing study (Phase 6.2/6.2A) to extend the life of the W78 warhead on Minuteman III, which has aged beyond its planned service life. Options are being considered for interoperability of the nuclear explosive package with the U.S. Navy's W88 delivery system. In addition to addressing aging concerns, the W78/88-1 life-extension program (LEP) is examining incorporation of enhanced safety and security features as part of the changes that would be made to the warhead. Technical information developed at LLNL, which is the lead nuclear design laboratory for the effort, is enabling an early focus on the preferred design concept and down-select of the pit and nuclear explosive package.

LLNL is partnered with Sandia National Laboratories–California to develop concepts for the U.S. Air Force's bomber-delivered Long-Range Stand-Off (LRSO) weapon to support the NNSA goal of an early warhead down-select. The California team is considering options ranging from minimal changes to existing warheads to full LEPs, identifying best choices for the LRSO weapon, and recommending the prompt start of a Phase 6.2 study.

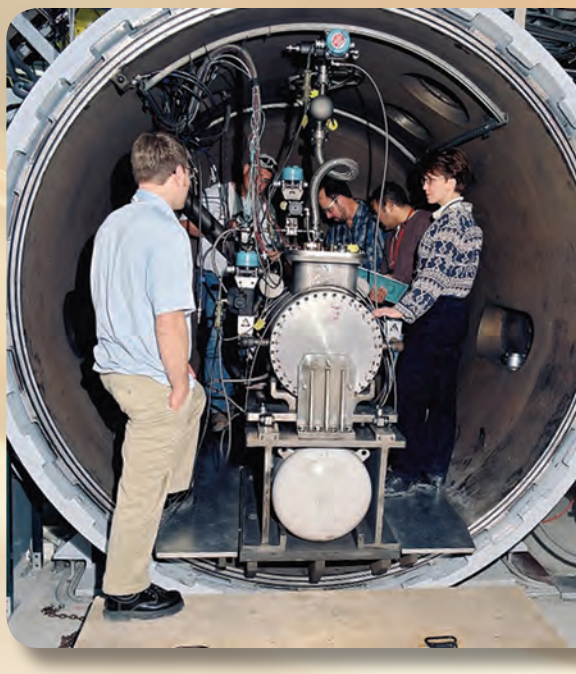
In support of LEPs, LLNL is exploring the potential use of additive manufacturing techniques for cost-efficient production of weapons parts. In addition, the Laboratory worked with Los Alamos to produce the first engineering-development-unit W87 pit, demonstrating the production of another pit design in the PF-4 plutonium facility at Los Alamos.

Advances in Supercomputing

In April 2013, the Sequoia supercomputer transitioned to classified operations as a user facility in support of the Stockpile Stewardship Program. The IBM BlueGene/Q machine, capable of performing at 20 petaflops (quadrillion



Record-breaking simulations included a particle-in-cell simulation of intense laser light interacting with a dense plasma that used all 1,572,864 cores of the Sequoia supercomputer.



Foster Celebration
Celebration of John S. Foster, Jr.'s, 90th birthday included a roundtable discussion of nuclear weapons program evolution since Foster's breakthrough weapon primary design in the 1950s. The panel included essentially all former leaders of LLNL's primary-design division (B Division). Foster (far left) was joined by two former LLNL directors, Michael May (second from left) and Michael Anastasio (fourth from right), and Los Alamos Director Charles McMillan (second from right). Current B Division leader Michael Dunning (right) moderated the panel.

floating-point operations per second), demonstrated its remarkable capabilities in record-breaking simulations performed before the transition. For example, an international team of scientists won the Gordon Bell Prize in 2013 for a 13-trillion-cell fluid dynamics simulation of a collapsing cloud of bubbles.

Sequoia greatly enhances the ability to assess the condition of the stockpile, understand aging issues and resolve significant findings in weapons systems, and carry out LEPs. Sequoia enables higher-fidelity physics models in simulations and makes it possible to run large suites of simulations to better quantify uncertainties.

As Sequoia moved into classified operations, NNSA reached a key step (Critical Decision-0) toward acquisition of the next major computer platform to be deployed at LLNL. The machine, called Sierra, is planned to go into service as a tri-NNSA-laboratory resource in FY2018. LLNL is working with Argonne and Oak Ridge national laboratories on the five-year effort. A request for proposals will be released from LLNL in FY2014 for the acquisition of three systems, one for each laboratory. It is expected that the LLNL system will operate at between 100 and 200 petaflops (peak speed).

Stockpile Stewardship Experiments

A wide range of experimental activities in FY2013 advanced nuclear-weapons scientific understanding and supported the needs to sustain the stockpile and pursue LEPs. Exceeding last year's pace of experiments, researchers fired seven "hot" shots and six surrogate shots at LLNL's Joint Actinide Shock Physics Experimental Research (JASPER) facility, located at the National Nuclear Security Site in Nevada, to investigate the properties of plutonium shocked to extreme conditions. In addition, 86 high-energy-density science experiments were fired at the National Ignition Facility, a threefold increase over FY2012 (see p. 6 for details).

Laboratory scientists fast-tracked work on two integrated weapons experiments (IWEs) at hydrodynamic testing facilities at Los Alamos and the Contained Firing Facility (CFF) at LLNL's Site 300. A surety experiment also was conducted at CFF related to the W78/88-1 LEP. In one case, typical preparation time of 18 to 24 months was shortened by a factor of two. Altogether, five IWEs were prepared for execution in early FY2014. Other experimental activities included tests at Site 300 to understand the thermal loads on the B83 bomb and ensure that the weapon system meets performance requirements.

Joint Actinide Shock Physics Experimental Research (JASPER) team members stand inside the outer containment vessel and inspect the sealed inner chamber, which houses a plutonium target.

LLNL gathered data at Site 300 for validating models used to understand the thermal loading on the B83 nuclear bomb (trainer unit shown) and ensure that the weapon meets performance requirements. The six-week-long test entailed cycling a highly instrumented unit through temperature extremes.

National Ignition Facility

Supporting stockpile stewardship through a wide range of nonignition experiments and pursuit of laser fusion ignition, and operating as a national user facility for high-energy-density science

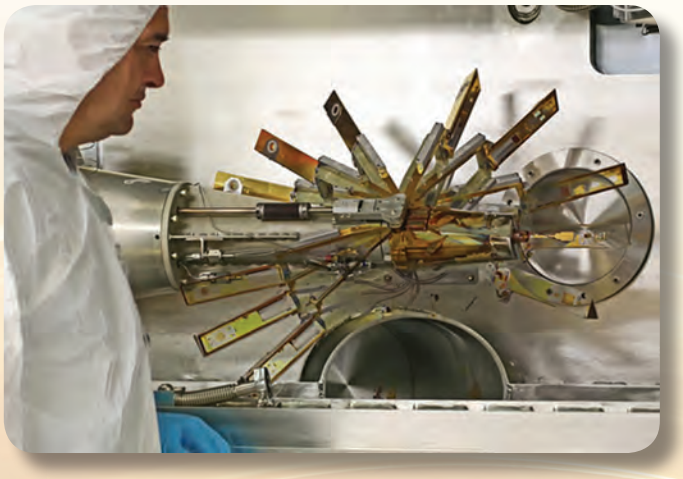
During FY2013, a total of 337 system shots were fired at the National Ignition Facility (NIF), including 72 fusion ignition experiments and 86 shots for high-energy-density science applications. NIF is serving as a highly productive cornerstone of stockpile stewardship, providing valuable insights into the nature of the universe and advancing the prospect of laser fusion as a carbon-free energy source.

Record-Setting Neutron Yield

Experiments at NIF clearly demonstrated "self-heating," a mechanism needed to achieve ignition and sustained fusion burn. The shot on September 28, 2013, imploded a tiny cryogenically cooled deuterium–tritium capsule and broke the NIF record for number of neutrons produced (5×10^{15} neutrons). Alpha particles (helium nuclei) from fusion reactions further heated the plasma in a central hot spot and increased the total yield by nearly 80 percent. Altogether, more energy was produced (14.4 kilojoules) than was imparted to the imploding deuterium–tritium fuel. A later shot further improved performance.

The highly successful shot was part of the "high-foot" campaign to address breakup of the capsule shell that was observed in earlier experiments. "High-foot" refers to the shape of the laser pulse, which is modified in a way that resists hydrodynamic instabilities and breakup of the shell but reduces overall compression in the implosion.

At shot time, the National Ignition Facility (NIF) control room is the focal point of activities. Experiments are controlled and orchestrated by the integrated computer control system that monitors about 60,000 control points, including mirrors, lenses, motors, sensors, cameras, amplifiers, capacitors, and diagnostic instruments.



A multiple-exposure photograph captures Cryogenic Operations technician Frank Cebreros testing the opening of the target shroud in preparation for a tantalum equation-of-state experiment. Two Y-shaped arms form a shroud around the cold target to protect it until they open five seconds before a shot.

Experimental results were remarkably close to simulations and serve as an important tool for understanding and improving performance. The accomplishment constitutes a key step along the path to ignition described by NNSA in a December 2012 report to Congress. Achieving ignition is a vital goal in support of stockpile stewardship and provides an option for long-term energy security.

High-Energy-Density Science Experiments

Groundbreaking campaigns of high-energy-density science experiments at NIF in FY2013 explored wide-ranging physical phenomena. Altogether, 86 high-energy-density shots provided valuable data about the properties of materials at extreme conditions, the interaction of matter with intense radiation, and hydrodynamic turbulence and mixing. These issues are critical to assessing the nuclear weapons stockpile and improving the performance and predictability of fusion ignition experiments.

For example, researchers from Los Alamos National Laboratory and the United Kingdom's Atomic Weapons Establishment—working with the NIF team—conducted five more experiments in the Pleiades campaign. They are studying how x-ray radiation interacts with and burns through matter at temperatures of several million degrees. Another series of shots studied the behavior of iron at eight million times Earth's atmospheric pressure, providing

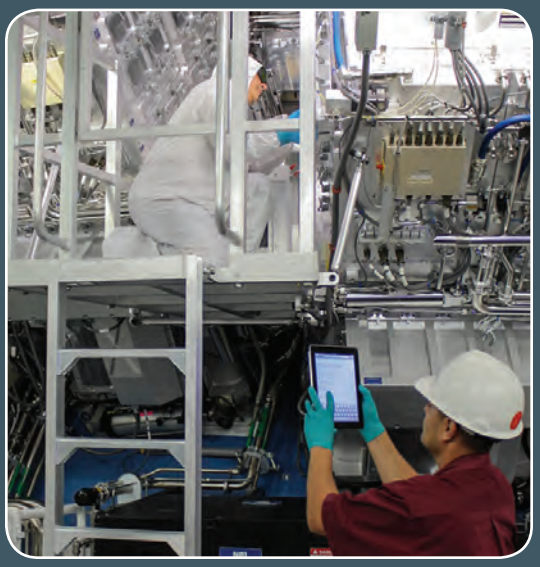
clues to the formation and structure of planets. Similar experiments for the Stockpile Stewardship Program characterized the equation of state of tantalum. In addition, scientists conducted a series of shots that replicated, at very small scale, physical processes occurring in a nuclear detonation. These nonnuclear tests support efforts to improve U.S. forensic capabilities that would be relied on to quickly detect, locate, and assess the occurrence of a nuclear blast.

Effective Operations as a User Facility

In FY2013, NIF transitioned to a user facility for fundamental high-energy-density science, stockpile stewardship, and other national security applications. Experimental programs are guided by the Science on NIF Technical Review Committee and a newly formed NIF Management Advisory Committee. Support capabilities have grown considerably to meet strong user-community demand for both large numbers and different types of experiments. The NIF team fabricated 317 high-precision targets in FY2013 with over 40 new target types. The number of experimental configurations, or "platforms," fielded has increased from six in FY2010 to about 35 in FY2013.

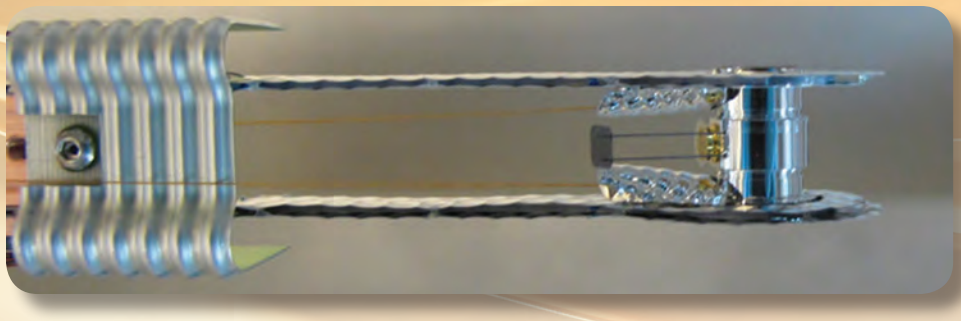
In addition, 13 new diagnostic capabilities were installed to support more types of experiments and significantly enhance the kinds of data that can be collected. As an example, the new Target Diffraction In-Situ system was used to measure the growth of instabilities in the structure of tantalum at high pressure and determine the material's strength. Important milestones were also reached in installing the Advanced Radiographic Capability at NIF, which will enable researchers to record a series of snapshots revealing the dynamics of materials under extreme temperatures and pressures.

Operational efficiency is also continuously improving. The effort per experiment (average number of person-hours per shot) has decreased from 6,000 hours in FY2009 to approximately 2,000 hours in FY2013. Critical path analyses along with process and equipment improvements have decreased shot turnaround time by a factor of two. For example, the time between a neutron-yield experiment and a subsequent shot has been reduced from 57 to 21 hours. As discussed on p. 17, significant advances have also been made in environmental management, such as hazardous waste reduction.



Efficient NIF Operations
Juan Soto (right) assists Rich Moore in reinstalling continuous phase plates in Level 3 of the target bay. In a week's time in July, the NIF Target & Handling team completed a remarkable 99 final optics transactions. Among the many improvements in NIF operations, the efficiency of changing user optics within the target bay has approximately doubled, and the average number of person-hours per shot has decreased by about a factor of three since FY2009.

Technicians Steven Smith and Max Bergonia install mirror alignment equipment for the Advanced Radiographic Capability (ARC), developed to provide details about material dynamics at extreme conditions. Commissioning of ARC will begin in FY2014.



The NIF team conducted experiments to measure the hydrodynamic growth of a pre-imposed "ripple" on the wall of an ignition capsule during an implosion. A radiograph is produced using an x-ray backlighter located next to a hohlraum (far right) that encloses the precision capsule. The high-quality data obtained are compared to simulation results.

Global Security

Reducing the threat from terrorism and weapons of mass destruction and enhancing global stability

LLNL applies its exceptional capabilities to solve pressing issues affecting global security. Researchers develop advanced technologies to prevent the proliferation or use of weapons of mass destruction. They also provide enhanced capabilities across the government to address current and emerging threats. Our technical experts support international engagement in nonproliferation, threat reduction, and nuclear-test monitoring activities and pursue programs in chemical/biological counterterrorism and explosives security. Innovations in space situational awareness and cyber defense help strengthen national security in an interconnected world.

Biodetector Advances

In groundbreaking cancer research, scientists discovered a herpes virus in bladder cancer specimens using a Livermore-developed biodetector. Published in the journal *Tumor Biology*, the study is the first ever to link the virus to the seventh most common human malignancy. The Lawrence Livermore Microbial Detection Array (LLMDA) can detect more than 3,000 viral species and 2,000 bacteria species using 388,000 DNA probes on a small glass slide in its current version. Also used to test vaccine safety, the LLMDA has been licensed to St. Louis-based MOgene LC for a broad range of possible applications, including food safety, law enforcement, and medicine.

Biologists James Thissen (right) and Crystal Jaing work with a slide in the Lawrence Livermore Microbial Detection Array, which can detect greater than 5,000 different microbes.

In the Federal Laboratory Consortium's technology transfer awards, a team from LLNL and the Environmental Protection Agency (EPA) won an Outstanding Partnership Award for developing the Rapid-Viability Polymerase Chain Reaction (Rapid PCR) technology to boost the speed, safety, and cost-effectiveness of testing for anthrax spores. The technology allows a testing lab to process 150 samples in as little as 48 hours—instead of the two days and 30-sample-per-day limit of previous methods. Rapid PCR has been adopted by the EPA's Environmental Laboratory Response Network for responding to possible future anthrax attacks.

Ongoing Fukushima Assistance

Livermore continued to assist Japan in its response to the situation in and around the Fukushima Dai-ichi Nuclear Power Plant. With its broad knowledge of the mechanisms of cesium's environmental behavior, Livermore began

Livermore scientist Sarah Chinn prepares a sample for analysis by nuclear magnetic resonance, one of the techniques used to detect chemical weapons agents and related substances. LLNL is one of only two U.S. laboratories accredited to perform such analysis under the Chemical Weapons Convention.

(Courtesy of U.S. Enrichment Corporation.)

HEU Transparency Program
In its 20th year of operation in 2013, the U.S.–Russia Highly Enriched Uranium (HEU) Purchase Agreement achieved its goal of converting more than 500 metric tons of HEU to safer low-enriched uranium for use in American nuclear power plants (shipping containers are shown). Livermore researchers supported the HEU Transparency Program by serving on and coordinating the U.S. monitoring team. They provided advanced equipment such as an LLNL-developed portable nondestructive assay system and maintained a repository of the collected monitoring data.

partnering with the University of Tokyo to enhance understanding of cesium uptake in plants. An LLNL researcher toured the Dai-ichi site and briefed the Japanese government and Tokyo Electric Power Company on how the Laboratory's know-how could be applied to short-term cleanup and the long-term restoration, decontamination, and decommissioning of the plant, as well as broader remediation in Japan. LLNL researchers and DOE staff participated in a third workshop for Fukushima responders, where the head of Livermore's Marshall Islands Program explained the remediation of cesium, drawing on the Laboratory's track record as the only DOE site experienced with cesium remediation through reoccupation.

Sleuthing for Chemical Weapons

The Laboratory was recertified by the Organisation for the Prohibition of Chemical Weapons (OPCW) as one of only two in the United States accredited to analyze suspected chemical weapon agents under the Chemical Weapons Convention. After a lapse in accreditation, the Laboratory received an "A" grade in three consecutive semiannual tests starting in late 2011, attaining recertification in early 2013. OPCW was awarded the Nobel Peace Prize in 2013 for its extensive efforts to eliminate chemical weapons.

The Laboratory uses techniques such as gas chromatography and nuclear magnetic resonance spectroscopy to detect chemical weapons agents and chemicals that indicate their manufacture. Advancing the state of the art, LLNL developed a new method—combining heteronuclear single quantum coherence and diffusion-ordered spectroscopy—for identifying organophosphorus compounds, which are common among chemical weapons agents.

Making Flying Safer

Protecting aviation from terrorist threats is an unforgiving task: measures to detect explosives must be right every time. Against this ever-evolving threat, LLNL seeks to develop a predictive capability to improve explosives detection and mitigation by combining its world-leading computational resources with explosives expertise. In FY2013, the Laboratory concluded a project for the Department of Homeland Security to computationally study aircraft vulnerability to homemade explosives. Researchers created a structural model of an aircraft and used multiphysics and other codes to generate important data such as threshold explosive masses for catastrophic damage at various locations in an aircraft.

Hypersonic Munition Tested

LLNL explosives expertise also supports the U.S. military. An important effort is the design and development of an advanced kinetic-energy warhead for the Department of Defense. Preparations in FY2013 led to a highly successful hypersonic sled test at Holloman Air Force Base in October 2013. The test "demonstrated that the warhead functions in a flight-representative environment," said a Department of Defense representative, bringing the Conventional Prompt Global Strike program "one important step closer" to its ultimate objective. The Laboratory has served as technical lead and integrator of the effort to simulate the warhead's hypersonic operating environment, using simulations and experiments—including an earlier sled test in July—to design components and test key issues related to material strength, aeroheating, ablation, and aerodynamic flight stability.

The Laboratory has developed improved protocols for testing and screening luggage, and its computer algorithms have been adopted for scanning equipment deployed to airports across the nation. Here, Harry Martz, who was appointed by the National Research Council to chair a committee on airport passenger screening, prepares a case that will be checked to acquire x-ray signature data in an explosives detection system.

Energy and Environment

Using science and technology to provide clean, abundant energy; protect the environment; and understand and mitigate climate change

Laboratory researchers apply leading-edge capabilities to develop efficient and environmentally benign energy technologies and to investigate the processes behind climate change.

Tracking Deeply Sequestered Carbon Dioxide

A team led by an LLNL researcher announced the world's deepest use of electrical resistance tomography (ERT) to track carbon dioxide (CO_2) sequestered in a geologic formation more than 10,000 feet deep. The team, working in an oil and gas field in Cranfield, Mississippi, obtained time-lapse ERT images of more than 1 million tons of sequestered CO_2. They demonstrated that the technique, which requires inserting an array of electrodes down deep boreholes, can monitor the movement of CO_2 in a complex geologic formation. ERT could have application as a remote monitoring and early warning system to track containment in reservoirs of sequestered CO_2. Deep geologic sequestration of CO_2 is being evaluated internationally to mitigate the effect of greenhouse gases produced during oil- and coal-based energy generation.

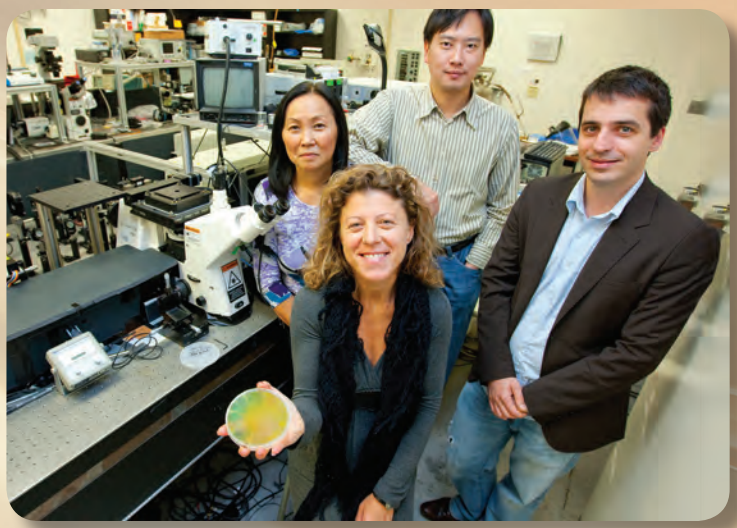
"Black Metal" Solar Energy Breakthrough

LLNL engineers developed new nanostructured metal materials that could enable photovoltaic solar cells that harvest solar energy much more efficiently. The plasmonic "black metals" are actually an extension of the concept of black silicon. When silicon is processed in a certain way, such as being roughened at the nanoscale level, it traps light by multiple reflections, increasing its solar absorption. Unlike other black metals, which have been produced with random nanostructures, the Livermore material uses nanopillars and is "tailor made" to have low reflectivity and high absorption of visible and infrared light. By controlling the dimensions of the nanopillars, the researchers can essentially fine-tune them to reliably absorb the desired solar wavelengths. The work was featured as the cover story for the May issue of *Applied Physics Letters*.

Human Fingerprint in Climate Change

A Laboratory scientist led an international team that compared simulations of 20 different computer models to satellite observations, concluding that atmospheric temperature changes are clearly related to human activities. The observations and simulations show a distinctive pattern: the lower stratosphere cooled markedly over the past 33 years, primarily because of human-caused depletion of stratospheric ozone; and large-scale warming occurred in the lower troposphere—most noticeably over the Arctic—mainly driven by human-caused increases in

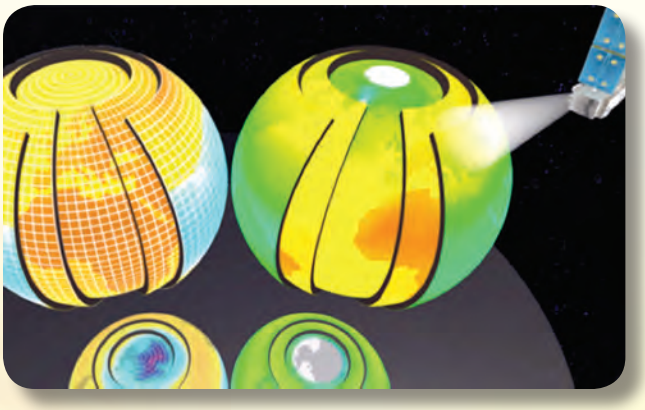
A worker lowers a borehole casing fitted with cables from an electrical resistance tomography (ERT) array. Images from this use of ERT—the world's deepest application to date—tracked the movement and concentration of carbon dioxide sequestered in the formation.



LLNL engineer Tiziana Bond—center, holding a silicon wafer etched with nanopatterns—with researchers Elaine Behymer, Allan Chang, and Mihail Bora. Their new plasmonic "black metal" material holds the potential for ultrahigh-efficiency solar cells.

greenhouse gases. The new climate models analyzed by the team formed the scientific backbone of the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Over the past three years, Laboratory scientists have made significant contributions to the underlying assessments and preparation of the IPCC report. LLNL's Program for Climate Model Diagnosis and Intercomparison leads the Earth System Grid Federation effort for DOE. The federation stores and distributes worldwide terascale data sets from coupled ocean–atmosphere global climate model simulations.

The California Energy Commission funds research at LLNL to examine load-balancing issues as more solar and wind resources are added to the grid. California is implementing a Renewables Portfolio Standard that requires the state to derive at least 33 percent of its electricity from eligible renewable energy resources by 2020. In FY2013, researchers ran thousands of supercomputer simulations to determine the value of using new energy storage technologies and demand-response initiatives to keep California's complex grid system operating affordably and reliably.



An animation depicts findings on atmospheric temperature change over a 32-year period as simulated with a model (left globe) and determined from satellite observations (right globe).

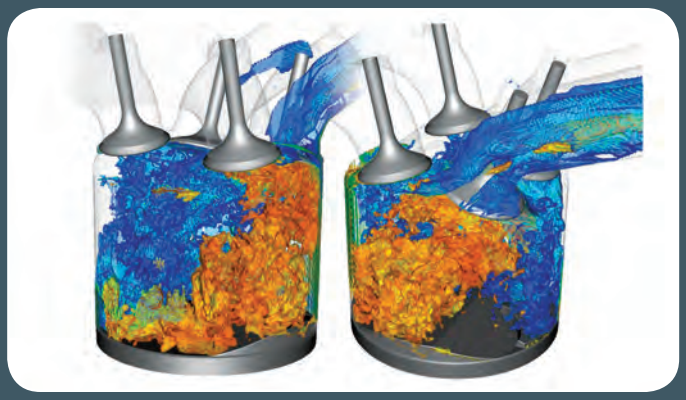
A material discovered through computational screening can capture methane (CH_4), an important greenhouse gas. Dark blue represents the optimal sites for trapping methane. The arrows represent interaction distance between sites.

New Methane-Capturing Material

LLNL and the University of California (UC) at Berkeley announced the joint discovery of new materials that capture methane, a far more potent greenhouse gas than CO_2 and a substantial contributor to climate change. Methane, unlike CO_2, interacts very weakly with most materials, making capture of the gas a significant challenge. The Livermore–UC Berkeley team computationally screened numerous materials, including roughly 100,000 zeolites. In simulations, one specific zeolite, dubbed SBN, captured enough medium-purity methane to yield high-purity methane, which could be used to generate electricity. Other zeolites were shown capable of concentrating dilute methane streams into moderate concentrations and so could be used to treat coal-mine ventilation air.

Wind Power and Smart-Grid Technology

The California Public Utilities Commission and the California State Legislature approved a five-year agreement that will provide three California public utilities access to Livermore's high-performance computing and expertise in engineering and applied science. Under the initiative, called California Energy Systems for the 21st Century, the Laboratory will assist in areas such as cybersecurity for the state's electrical grid.



The hpc4energy Program

In one of the hpc4energy projects, Robert Bosch, LLC researchers worked with Laboratory computer scientists to scale a Bosch simulation code to run efficiently on one of Livermore's supercomputers. They reduced the calculation time for each engine cycle by 70 percent and improved the model resolution, allowing them to examine combustion in greater detail than the Bosch computer system can produce. The hpc4energy incubator program focused on six selected pilot projects for Laboratory–industry partnerships to advance innovative energy technologies using high-performance computing.

Science and Technology

Expanding the boundaries of scientific knowledge and advancing the technological state of the art to solve problems of national and global importance

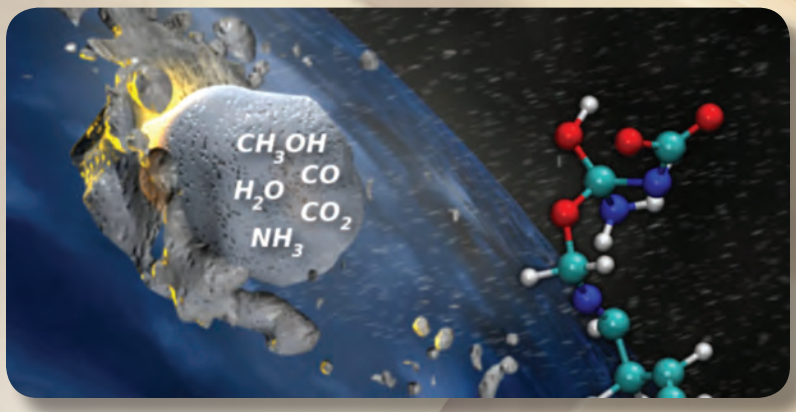
Science and technology are central to addressing many of the most difficult problems of the 21st century. Research using LLNL's multidisciplinary scientific expertise and its world-class experimental and computational resources leads to exciting discoveries and innovative solutions.

Evidence for "Life Through Icy Impacts"

Researchers have furthered the theory that comets striking an ancient Earth could have provided the building blocks of life. A Laboratory scientist performed quantum molecular dynamics simulations of shocks in a CO_2-rich ice, similar to what is found in comets. Production of significant quantities of simple carbon–nitrogen compounds was predicted, suggesting that cometary impacts could have synthesized prebiotic molecules without catalysts, ultraviolet radiation, or other special conditions. In 2013, gas-gun experiments performed in England on comet-like ice confirmed the simulation results and demonstrated that hypervelocity impacts could have produced several kinds of amino acids. The findings also clarify the role of such impacts in forming life-building compounds on other planets.

Measuring the Spin of Black Holes

An international team including LLNL astrophysicists reported the first-ever definitive measurement of a supermassive black hole's spin rate, one of the few observable properties of a black hole. Previous measurements are uncertain due to the effects of obscuring, surrounding clouds. The finding was made with the two x-ray space observatories, NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) and the European Space Agency's XMM-Newton. Knowing the spin rate is important because the formation, evolution, and properties of a galaxy are closely linked with those of a supermassive central black hole. Laboratory scientists played key roles in the design and testing of the x-ray optics for NuSTAR.



Simulations and experiments showed that ancient comets carrying methane and other compounds could have produced the molecular precursors of life when they impacted Earth.

An artist's conception of a supermassive black hole surrounded by an accretion disk, with an outflowing jet of energetic particles believed to be powered by the black hole's spin.

New Discovery in Virus Transmission

With outbreaks such as severe acute respiratory syndrome (SARS) still trending upward, LLNL researchers have advanced knowledge of how new viruses from animal reservoirs can infect people. They discovered that the genetic diversity of a viral population within a host animal could allow a virus to adapt to certain conditions that enable it to reach a human host. The team identified a mutation in a coronavirus that enables the jump from pigs to humans and determined that the gene came from the virus's existing gene pool rather than spontaneous mutation. They also demonstrated that their technique—deep, high-throughput sequencing using overlapping read pairs—can detect mutations at ultralow frequencies. These advances could influence how future vaccines and antivirals are designed and tested.

Livermore's Monica Borucki examines cell lines used for virus studies as team members Jonathan Allen and Haiyin Chen look on.

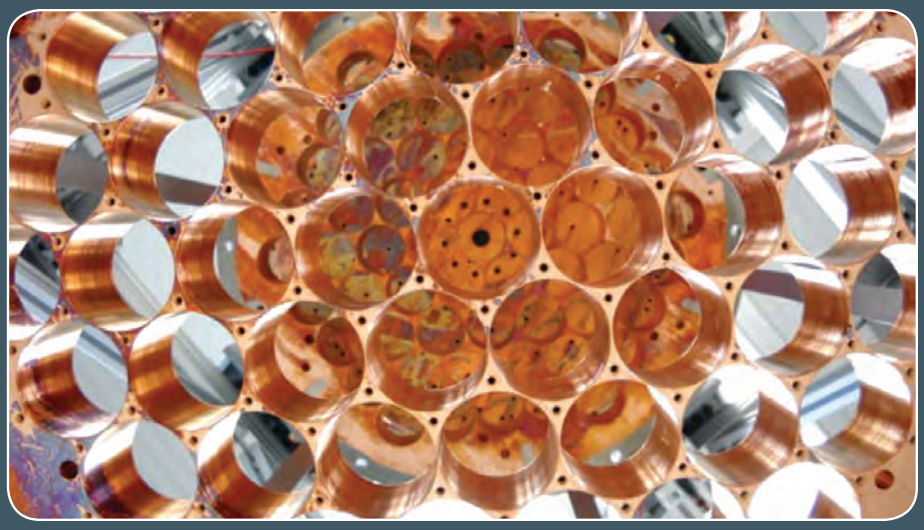
Celebrating 25 Years of Discoveries

Livermore's Center for Accelerator Mass Spectrometry (CAMS) marked its 25th year tackling scientific problems and global challenges. Successes in FY2013 include tracking radionuclides from the Fukushima Dai-ichi Nuclear Power Plant disaster (see p. 8) and helping to make a surprising discovery about the human brain—that the hippocampus, a small area involved in memory, makes new neurons well into adulthood. Neuron age can be determined from the amount of carbon-14 in the DNA hippocampus cells, which dates when the cells were formed. Carbon-14 in the atmosphere (and absorbed by plants that were eaten) spiked during the era of nuclear weapons testing and has declined at a predictable rate since the test ban. The researchers found that each year, 1.75 percent of all human hippocampal neurons are renewed. This neurogenesis could contribute to human brain function into adulthood and even play a significant role in human behavior.

Imaging Uncovers Surprise About Cell Membranes

LLNL researchers, with colleagues from the University of Illinois and the National Institutes of Health, developed a new method for mapping small molecules in cell membranes and made an important finding about cholesterol. The technique, which revealed some unexpected relationships among molecules within cell membranes, provides a new way of studying cell structure and ultimately its function. LLNL's nanoscale secondary ion mass spectrometer provided high-resolution images of the distribution of nitrogen-15-labeled sphingolipids, previously thought to associate with cholesterol to form small domains about 200 nanometers across. The images revealed that sphingolipid clustering was related less to cholesterol than to the cytoskeleton—the proteins underlying the membrane.

At Livermore's Center for Accelerator Mass Spectrometry, Ted Ognibene loads a sample in a tandem accelerator used mainly for biological research.



LUX Experiment

At the Large Underground Xenon (LUX) experiment, the world's most sensitive dark matter detector has seen no events yet. The result rules out some possibilities of what dark matter could be. A key component on the ultrasensitive detector, located nearly a mile underground, is the copper photomultiplier tube mounting structure (shown in the photo), which was designed and built by LLNL. Building on a synergistic overlap with nonproliferation detector programs, Livermore researchers have been involved in the LUX experiment since 2008.

Screening Drug Candidates Computationally

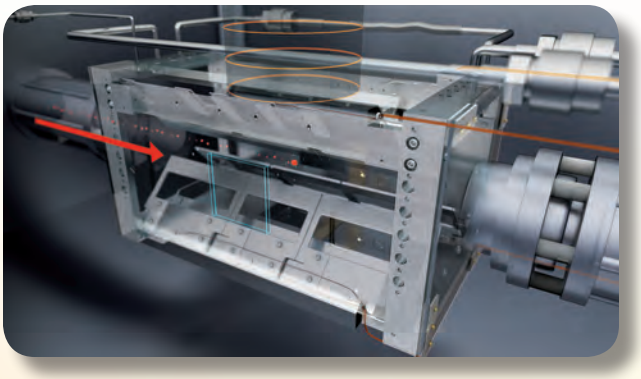
Computational scientists developed a new scheme for screening drug candidates using molecular docking—how well a candidate molecule "fits" into and binds to an active site in a protein molecule to be targeted by the drug. The team solved two roadblocks to wider use of the technique—its computationally intensive nature and scaling to supercomputing platforms—by developing a new hybrid scheme. They modified a popular open-source docking program from the Scripps Research Institute to create a new code, called VinaLC. A dramatic improvement in capability, VinaLC scales to more than 15,000 processors and is fast—one million compound-docking calculations take only 1.4 hours.

Z-pinch Simulation Breakthrough

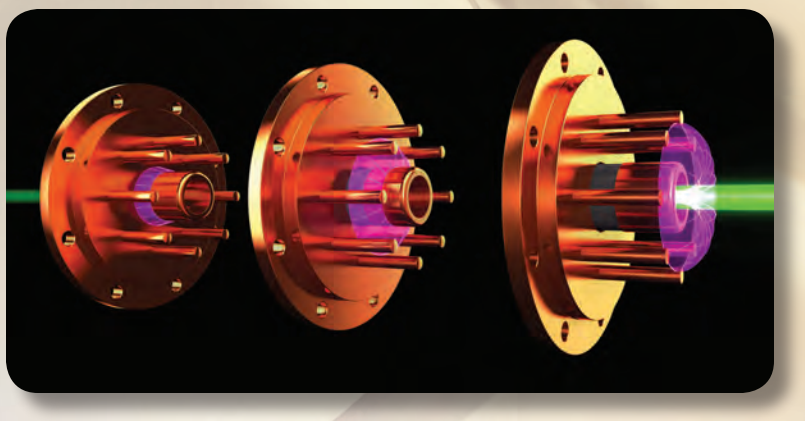
Livermore's plasma researchers demonstrated the first-ever fully kinetic model of a dense plasma focus Z-pinch device in a realistic geometry. The Z-pinch is a well-studied, classic plasma configuration, but it still defies scientists' ability to fully predict and understand its behavior. Simulations with the model, which tracks physical quantities at the particle level, reproduced key features of Z-pinch plasmas, including the ion beam, neutron outputs, and a type of instability long postulated to drive the dynamics in these plasmas. Simulations performed by the researchers also reproduce experimental neutron yields and high-energy beams for the first time. These results prompted the Defense Advanced Research Projects Agency to fund groundbreaking work at LLNL using Z-pinches to make compact neutron sources for applications beyond the previous state of the art.

New Ion Trap Finds "Undetectable" Particles

An LLNL physicist and collaborators across the U.S. and Canada developed and successfully tested a new ion trap that could revolutionize radioactive decay measurements. The new apparatus, which traps radioactive ions in free space, infers the properties of particles emitted in radioactive decays that are either difficult to detect (e.g., neutrons) or nearly impossible to detect (e.g., neutrinos) by measuring the recoil of other, easier-to-detect particles involved in the decay. Researchers showed for the first time that it is possible to reconstruct the number and energies of the neutrons emitted by a decaying nucleus by measuring the time of flight of the recoiling daughter nuclei to a nearby detector. They also used the ion trap to study the beta decay of lithium-8, determining the direction and energy of all emitted antineutrinos. The technology paves the way for testing the Standard Model of physics with unprecedented precision.



Livermore's new ion trap can find difficult-to-detect neutrons and neutrinos by measuring nuclei that recoil during decay. A successful demonstration paves the way for measurements that will test the Standard Model of physics.



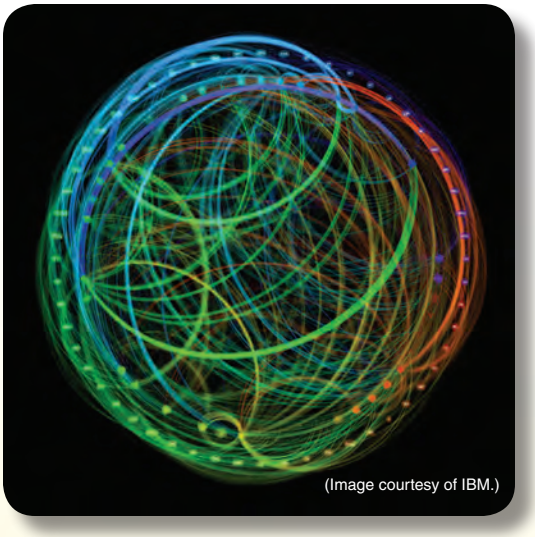
In this rendering of a Z-pinch, an umbrella-shaped plasma sheath (purple) is pushed down a cylindrical electrode, then collapses to create a dense region (white) that "pinches" and thereby accelerates an ion beam (green).

Water Signature in Exoplanet Spectrum

An LLNL astronomer working with an international team has made the most detailed examination yet of the atmosphere of a Jupiter-like planet beyond our solar system. Using the OSIRIS instrument on the Keck II telescope, they found on exoplanet HR 8799c chemical fingerprints of specific molecules indicative of a cloudy atmosphere containing water vapor and carbon monoxide. These results demonstrate how such telescopic resolution allows researchers to begin a new phase in probing planet formation.

Vulcan Contributes to Many Mission Areas

The Vulcan supercomputer at LLNL brings Sequoia's computing power to mission-directed work in national security, energy, bioscience, and atmospheric science programs. It is available for unclassified collaborations with industry and universities to advance science and boost U.S. economic competitiveness through technological innovation. Vulcan is based on the same IBM BlueGene/Q technology as the Sequoia platform, which proved its capabilities in record-breaking unclassified test runs before being switched over to classified work. For example, researchers performed the most powerful brain simulation ever, with 530 billion neurons and 100 trillion synapses. With a speed of 5 petaflops, Vulcan is one of the world's most powerful computers available for unclassified projects. The machine



This network of neurosynaptic cores represents the world's largest "wiring diagram" of a monkey's brain, achieved with the TrueNorth system running on the Sequoia supercomputer. The simulation reached a milestone of 530 billion neurons and 100 trillion synapses, making it the most powerful brain simulation ever. Since Sequoia has switched to classified work, such advanced simulations will now be conducted on Vulcan.

debuted at the number eight spot on the June 2013 Top500 list of the world's fastest supercomputers.

"Invention of the Year" and Five R&D 100 Awards

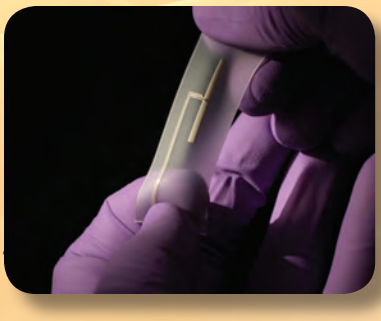
The artificial retina, a technology that the Laboratory played a prominent role in developing, earned a place in the top 25 best inventions of the year 2013 from *Time* magazine. The technology also garnered a 2013 best innovation designation by *Popular Science*. The LLNL team contributed three major components to the artificial retina development program. This DOE-funded project resulted in the creation of the first-ever retinal prosthesis—or bionic eye—approved in the United States by the U.S. Food and Drug Administration for blind individuals with end-stage retinitis pigmentosa. The invention was commercialized by Second Sight Medical Products, Inc., and is now called the Argus II Retinal Prosthesis System.

Livermore researchers also received five awards in the latest R&D 100 Awards competition, which recognizes the year's top 100 innovations with commercial potential. The winning technologies are: DNA-Tagged Reagents for Aerosol Experiments, a versatile material that can safely, reliably, and rapidly diagnose airflow in assessments of contamination and other scenarios; the Movie Mode Dynamic Transmission Electron Microscope, which captures billionth-of-a-meter-sized events at frame rates more than 100,000 times faster than conventional techniques; Mantevo Suite 1.0, the first integrated suite of miniapps (small software applications) for high-performance computing; the Laser Screening at High-throughput to Identify Energetic Laser Distortion, which reduces the time to screen 48 NIF laser checkpoints from 12 hours to less than 1 second; and Efficient Mode Converters for High-Power Fiber Amplifiers, which overcomes a key limitation of high-power fiber lasers by maintaining beam quality as power is increased. LLNL has received 148 R&D 100 Awards since the competition began in 1978.

The movie mode of the Livermore-designed dynamic transmission electron microscope (DTEM)—which enables scientists to better understand nanostructure growth, phase transformations, and chemical reactions—was recognized with an R&D 100 Award.

Novel Materials through Additive Manufacturing

Livermore materials scientists and engineers are developing a novel set of additive manufacturing techniques to create materials with bulk properties that do not exist in nature and micro-engineered materials to meet mission needs. In FY2013, they fabricated the world's stiffest ultralight material. The new material's microarchitecture—consisting of eight-pointed truss structures with considerable void space—represents the basis for an exciting new class of ultralight, stiff, and strong materials. With their ability to create micro- to macroscale structures with extreme precision, LLNL researchers are also using direct ink writing to engineer embedded sensors, polymer-lattice-ordered foams, unique radio frequency components, and stretchable conductive materials.



This stretchable, deformable patch-like structure houses an antennae designed to turn throat vibrations into a decipherable electric signal. The patch was manufactured using a direct ink-writing process, one of four additive manufacturing approaches being developed at Lawrence Livermore.

Industrial Partnering Statistics

In FY2013, Livermore obtained 84 new U.S. patents and filed 206 patent applications. The Laboratory also signed three new Cooperative Research and Development Agreements, executed 20 new licenses, and implemented a pioneering DOE Agreement for Commercialization of Technology (see p. 18). Licensing and royalty income for the year exceeded $8.2 million.

Safety, Security, and Sustainability

Demonstrating safety and security excellence and sustainable environmental stewardship in all Laboratory activities

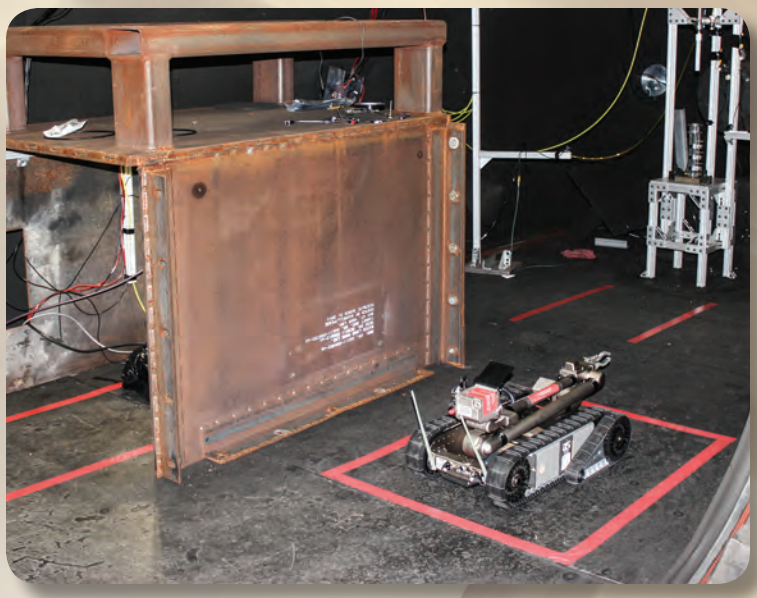
LLNL is committed to the highest level of performance in the areas of environment, safety, and health (ES&H) and security. Best practices are implemented throughout the Laboratory, and management systems provide for continuous improvement. The safety of employees and the public is ensured through prudent risk management coupled with active measures to prevent accidents.

Effective Environment, Safety, and Health

In 2013, the National Safety Council presented the Laboratory with a Significant Improvement Award for strong and improving safety performance. Key safety performance statistics are at a multidecade low. The FY2013 total recordable case (TRC) rate of 1.4 continues the prior year's excellent performance and represents a 25 percent decrease from 2011. More significantly, the days away, restricted, or transferred (DART) rate, which is a measure of severity of injuries, continues to improve (to 0.51) and is down by more than 50 percent over two years.

Inspections and assessments of worker safety and health programs demonstrated a high level of performance in key areas, with no major deficiencies. Continuous safety improvements include initiatives to implement additional injury and illness preventive measures, improve work control documentation, and streamline ES&H training (which has saved nearly $400,000 to date).

A state-of-the-art tritium-processing system has been installed to contain very small amounts of tritium in NIF targets and provide a mechanism for its safe disposal. More than $300,000 per year is saved through optimized tritium processing operations with infrequent exchanges and recycling of the tritium collection vessels.



Livermore Explosives iRobot (LEXI), shown in a firing tank at HEAF, is ready to move potentially unstable improvised explosives from a remote-controlled mixer inside a metal container (left) to a firing table (right). The tests of possible terrorist devices are conducted for the Department of Homeland Security.

New robotic systems were deployed in FY2013 to meet emerging needs for operational safety. A remote-controlled robot dubbed D2T3 (in honor of the fusion fuel isotopes deuterium and tritium) is now checking the beta and gamma radiation levels in the NIF target bay after high-neutron-yield experiments. LEXI (for Livermore Explosives iRobot) is at work in the firing tanks at the High Explosives Applications Facility (see figure at left).

Laboratory employees' focus on safe work practices is supported by high-quality, well-documented safety management programs. LLNL's Integrated Safety Management System holds Occupational Health and Safety Assessment Series (OHSAS) 18001 accreditation. LLNL also received International Organization for Standardization (ISO) 9001 accreditation for its Quality Management System (see p. 19). In addition, the Laboratory's Environmental Management System, which earned triennial recertification under ISO 14001, provides a systematic approach to identifying and reducing the environmental impact of Laboratory activities with strong focus on continuous improvement. In FY2013, LLNL operations at the main site and Site 300 near Tracy, California, were compliant with regulations and had no adverse impact to public health or local environment.

Award-Winning Sustainability Efforts

LLNL is enhancing the sustainability of site operations through heightened employee awareness, continual improvements to existing infrastructure, and collaborations with expanding research programs in renewable energy generation and energy efficiency. The steps taken in 2013 include replacing older boilers in buildings with high-efficiency models, rebuilding several chillers, and installing advanced metering to monitor electricity and natural gas usage. In addition, the Laboratory is undertaking sustainability demonstration projects and implementing award-winning sustainability improvements.

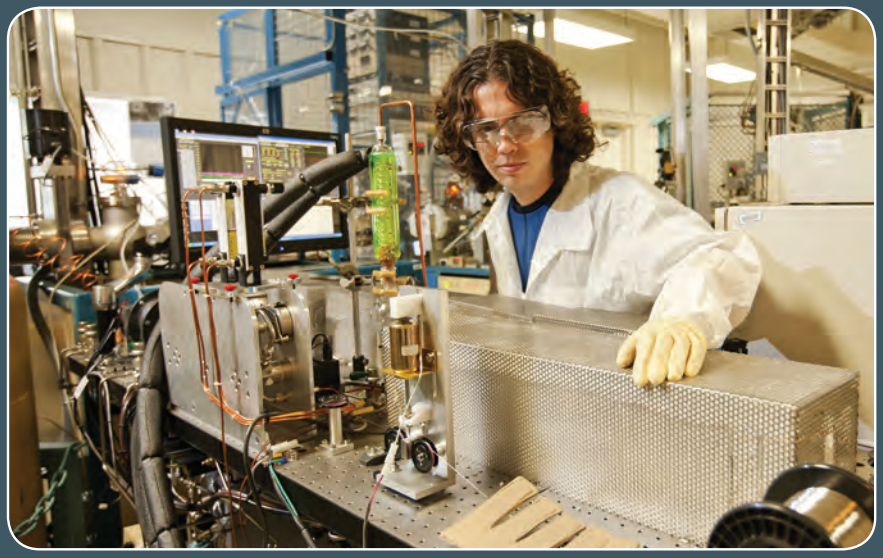
Two projects were recognized by NNSA with 2013 "Best in Class" Sustainability Awards, and a third project on sustainable landscaping was also honored. A "Best in Class" award went to the NIF team for its "active risk management" approach to reducing low-level radiological waste generation and preventing pollution. The team's effort has resulted in a reduction of an estimated 12,240 cubic feet of radiological waste per year, $1.3 million in consumables, and 40,000 person-hours per year of time spent managing NIF hazards.

The second "Best in Class" award was earned for LLNL's holistic waste reduction program, which builds upon a well-established recycling program that diverts more than 68 percent of the Laboratory's municipal waste from landfill. Recent efforts focused on expanding the types of items recycled and promoting a culture that considers reuse first. To date, an estimated $524,000 has been saved through reuse activities, and more than 30,000 pounds of items for which a recycling pathway was not previously available were recycled. An internal "Craigslist" application has been developed to facilitate reuse exchanges sitewide and better manage reuse of property.

Under sponsorship of the California Energy Commission, LLNL is partnering with Cool Earth Solar, Inc., to conduct a community-scale renewable energy integration demonstration project at the Livermore Valley Open Campus. The demonstration will include use of environmental and renewable energy forecasts to optimize heating, ventilation, and air-conditioning controls for building energy efficiency.

Site Security Changes Successfully Implemented

LLNL efficiently and effectively maintained secure operations in FY2013. The Laboratory's Security Organization conducted a strong self-assessment program and met all milestones on or ahead of schedule and within budget and completed a number of security enhancements. Major changes in LLNL's security posture were effectively implemented as the Laboratory transitioned to Security Category (CAT) III operations. Special nuclear material items that require the highest level of protections were removed from the site by September 2012—a year ahead of the schedule originally developed. Implementation of a compliant and effective CAT III security program, including changes to physical protection systems and staffing levels, reduced Laboratory security costs by approximately $40 million per year.



Safety Self-Assessment for DOE

In 2013, LLNL completed DOE's Safety Conscious Work Environment (SCWE) Self-Assessment, which included extensive document reviews, participation by more than 3,200 employees in a safety culture survey, and 258 personal interviews. Self-assessment results affirmed that LLNL programs and procedures support a positive safety culture, workers believe management values safety, and employees feel free to raise concerns and are empowered to stop or pause work as appropriate. Avi Thomas is shown working safely with a biological accelerator mass spectrometry instrument.

Management and Operations

Guiding the Laboratory's future course, managing the workforce, improving work processes and business practices, and achieving cost efficiencies

Excellence in management, business, and operations and attention to the needs of the workforce complement LLNL's outstanding performance in science and technology. FY2013 was a year of management changes, budget challenges, and steps to prepare for future successes.

Bret E. Knapp Named Acting Director

Bret Knapp has been named as the acting Laboratory director and president of LLNS, which manages Lawrence Livermore for DOE. Knapp replaces Penrose "Parney" C. Albright, who stepped down as director on October 31, 2013. Albright had served as Laboratory director since December 2011. Norman Pattiz, chairman of the LLNS Board of Governors, expressed appreciation for his "many contributions to LLNL and the nation."

A recognized expert in national security, Knapp previously spent more than 25 years at the Laboratory, working in nuclear weapons design and testing and leading programs in defense and nuclear technology development. In 2006, he joined the senior management team at Los Alamos National Laboratory, recently serving as principal associate director for the weapons program.

Creating the Laboratory's Future

Planning processes, program development efforts, and workforce adjustments in FY2013 set the stage for future programmatic successes. These efforts were complemented by initiatives to enhance work-environment quality. For example, LLNL implemented a policy that enables use of personal electronic devices (PEDs) in most workplaces.

LLNL was awarded $45 million to develop the High repetition-rate Advanced Petawatt Laser System (HAPLS) for the Extreme Light Infrastructure Beamlines facility under construction in the Czech Republic. HAPLS is designed to reach one petawatt (10^{15} watts) of power in ultrashort pulses ten times per second.

In accepting the responsibility to lead LLNS and LLNL, Bret Knapp stated that he was "honored to be selected" and "will work to continue and grow LLNL's cutting-edge science and engineering programs." He also acknowledged director Parney Albright "for his hard work and dedication to the people and programs at LLNL."

Previous restrictions limited PED use, which was an impediment to attracting scientific talent. Best practices and lessons learned were shared throughout NNSA.

Planning activities included a major update to the science, technology, and engineering investment roadmap. The roadmap describes new initiatives and strategic focus areas for program growth. It also identified core competencies that distinguish the Laboratory and are the focus of continual reinvestment to ensure future mission success. Possible future line-item investments at Livermore include six prospective projects submitted in LLNL's site plan and highly ranked by NNSA. We are working with NNSA to begin implementing an Electrical Infrastructure Upgrade Project.

Among the program-growth successes in FY2013, LLNL was awarded more than $45 million to develop and deliver a state-of-the-art laser system for the European Union's Extreme Light Infrastructure Beamlines facility, under construction in the Czech Republic. The agreement, which will deliver a laser system utilizing groundbreaking technologies, was a successful pioneering implementation of the DOE Agreement for Commercializing Technology (ACT) pilot program. Another key success was approval of the California Energy Systems for the 21st Century initiative (see p. 11).

Facing the prospect of future austere budgets in FY2014 and beyond, LLNS conducted a Self-Select Voluntary Separation Program to right-size the Laboratory for the future. Altogether, 399 employees chose to participate in

Small Business Outreach
In FY2013, LLNL procured through small businesses 62.6 percent of the $350 million spent for services and supplies, exceeding the DOE goal (which increased to 52 percent in FY2013) for the third straight year. Michelle Quick, Small Business Program Manager, and Kelly Miller, Supply Chain Management department head (seated left to right, with contract administrators Larry LeBel and Becky Ip), display the Small Business Achievement of the Year award received from DOE the previous year for outstanding performance.

the program, many with long and dedicated LLNL careers. Their collective years of service represent an extraordinary commitment to the Laboratory.

Livermore Valley Open Campus Growth

In April 2013, NNSA approved Critical Decision-0 for the development of the Livermore Valley Open Campus (LVOC), a 110-acre site at the eastern edge of Livermore and Sandia–California national laboratories. The two laboratories are finalizing input to support a Critical Decision-1 to acquire two new major facilities at LVOC. LLNL's existing High Performance Computing Innovation Center at LVOC has hosted 16,000 visitors and 1,700 events since opening in June 2011. A much larger new facility is needed to further expand high-performance computing partnership projects. In March 2013, LLNS released a request for information from parties interested in potential leases at LVOC.

Certified Quality Management and Assurance

Following an audit of LLNL's Quality Management System (QMS) in the summer of 2013, the auditor recommended ISO 9001 certification for the Laboratory. Certification is indicative that systems are in place for LLNL managers to make informed decisions based on employee feedback, internal assessments, external audits, and other tools for continual improvement. QMS is complemented by LLNL's Contractor Assurance System (CAS), which continues to mature. CAS is used to measure, improve, and demonstrate performance. It is a primary tool of the Laboratory's Management Assurance System, which provides assurance to NNSA that LLNL's mission objectives and contract requirements are met.

LLNS Board of Governors Activities

The LLNS Board of Governors and its committees provide oversight in critical areas related to mission and mission-support activities. The committees delve into their specific areas, and members participate in external review committees and Functional Management Reviews (FMRs). In FY2013, LLNS held four Directorate Reviews and six FMRs in selected topical areas. FMRs provided recommendations to improve preventative maintenance, expert evaluation of the effectiveness of LLNL nuclear safety basis procedures, validation of selected safety procedures, affirmation that LLNL's CAS meets requirements, and assistance to better integrate LLNL's and LANL's cyber risk management programs. Nearly 100 reviews have been conducted since 2007, resulting in more than 480 recommendations acted on by LLNL managers to improve Laboratory performance.

Shown in an artist's rendering, the permanent High Performance Computing Innovation Center at the Livermore Valley Open Campus will enable expanded collaborations in stockpile stewardship, energy and infrastructure, cybersecurity, biosecurity, advanced manufacturing, and big data analytics.

Community Connections

Supporting local communities through science education and charitable giving

The Laboratory is committed to being a valued and contributing member of the community, supporting a wide range of activities in science and engineering outreach and education. Each year employees generously contribute to local communities through charitable giving and volunteer efforts. In addition, the LLNS gift program provides support to community science and math education and cultural arts.

Saturday Science That Sizzles

LLNL's Science on Saturday (SOS) lecture series for middle- and high-school students again played to sold-out crowds. More than 5,000 people attended a total of 12 lectures held in Livermore, Tracy, and Brentwood. Laboratory researchers partnered with local science teachers in discussions demonstrating life-saving diagnostic devices, NASA's NuSTAR mission, detection of pathogens, and development of biofuels. These presentations were recorded for the University of California's TV website (uctv.tv) and YouTube. SOS videos have been viewed via the Internet more than 10 million times over the past five years.

Fun with Science

Each year, more than 6,000 kids in the 4th and 5th grade get up close and personal with science through myriad hands-on "Fun with Science" experiments. LLNL employees and retirees give students an understanding of scientific phenomena and help prepare them for science education at the middle- and high-school level. "Fun with Science" also makes annual treks to remote areas of Alaska to present to Inuit children.

Wearing defraction glasses, students in Noorvik, Alaska, enjoy a burst of color in an optics demonstration with strobe light. A "Fun with Science" road show reached out to 400 students in villages in the far north. Travel was funded by LLNL's vendor for supplemental labor, Akima, LLC, which has a strong connection to Alaska.

The Laboratory's educational outreach includes LLNL cosponsorship with Sandia National Laboratories of "Expanding Your Horizons," held in Stockton this year. The conference serves to spark interest in math and science for girls in grades 6–12. Wind power was one of the many topics highlighted for the 400 attendees.

Teacher Research Academies

More than 100 current and pre-service science teachers participated in summer Teacher Research Academies. A new academy was launched to introduce teachers to computer modeling and simulation. Technical communication workshops were added for both teachers and students to enhance their skills in technical writing and presentation. LLNL also supported a teacher–student research partnership program in which participants apply bioinformatics tools to sequence DNA samples, leading to publications in the GenBank DNA Sequence Database. This past year, more than 20 student-submitted unique gene sequences were accepted for publication in the gene database.

Curriculum That Cuts to the Core

Throughout 2013, Bay Area K-12 science teachers faced the challenge of supporting new Common Core state standards in literacy and math. In response, LLNL expanded its professional development academies to help teachers gain the key skills needed to meet this challenge for two high-demand topics. In computer modeling, LLNL technical staff teamed with local high school department heads to offer a two-week classroom-ready introduction to basic simulation software. In technical writing, LLNL's practical treatment of ways to meet Common Core requirements received an enthusiastic response from science teachers not only at an on-site summer workshop, but also in highly customized sessions hosted by the San Joaquin County Office of Education and the San Ramon

Ghoulish characters show up for the "Run for HOME," which kicks off the Helping Others More Effectively (HOME) charity campaign at the end of October. Best costume winners receive gift certificates that they can donate to the charity of their choice.

Guests find a healthy free meal at the Open Heart Kitchen, which serves those that are struggling in the Livermore, Pleasanton, and Dublin area. LLNL employees and retirees volunteer to help, and the charity is supported through the HOME Campaign.

Valley Unified School District. The Tri-Valley Education Collaborative, which coordinates career technical education for Livermore, Pleasanton, Dublin, and Las Positas College, also featured LLNL's Common Core resources at their December general meeting for teachers.

LLNL-Sponsored Science Fair Continues to Grow

Approximately 600 middle- and high-school students—twice the 2012 number—and more than 100 teachers from 18 school districts participated in the Alameda County Science and Engineering Fair (ACSEF). More than 170 awards were distributed for 1st, 2nd, and 3rd place and honorable mention, and 60 special awards from national and local government and industry sponsors also were presented. This event grew out of the extremely successful Tri-Valley Science and Engineering Fair, organized for 15 years by LLNL. With its countywide focus, ACSEF reaches a very broad and diverse population of students and teachers and provides an avenue of scientific outreach that had previously been missing from Alameda County.

Livermorium Celebration

On June 24, 2013, Mayor John Marchand (shown with LLNL Director Parney Albright), dedicated Livermorium Plaza, a gathering spot centrally located in downtown Livermore. Element 116, one of six elements discovered by a team of Laboratory and Russian scientists, was named livermorium by the International Union of Pure and Applied Chemistry. The day of celebration included a technical colloquium at the Laboratory and certification presentation by Congressman Eric Swalwell (CA-15).

HOME Campaign and Community Gifts

More than $3.5 million was raised in the Laboratory's HOME (Helping Others More Effectively) Campaign, an annual charitable drive that benefits community and nonprofit agencies in the Tri-Valley, San Joaquin Valley, and greater San Francisco Bay Area. Employees pledged a total of $2,540,292, and LLNS contributed $1 million in matching funds.

At a ceremony at the LLNS office in Livermore, acting Director Bret Knapp presented checks totaling $100,000 to the recipients for the 2013 LLNS Community Gift Program. LLNS received 72 applications totaling nearly $670,000 in requests, and 24 were selected for awards through a committee review process. The majority of these awards serve children in the Tri-Valley and San Joaquin County, with a focus on science, math education, and cultural arts.

Workforce Recognition

Acknowledging exceptional performance and expertise

The challenges of LLNL's mission require a workforce of exceptionally talented and dedicated employees. The many awards and honors received by Laboratory personnel are testament to their expertise and the impact of their work.

Gordon Bell Prize

The 2013 Gordon Bell Prize for peak performance was awarded to scientists at ETH Zurich and IBM Research, in collaboration with the Technical University of Munich and LLNL for a bubbles simulation performed on the IBM BlueGene/Q Sequoia machine (see cover graphic).

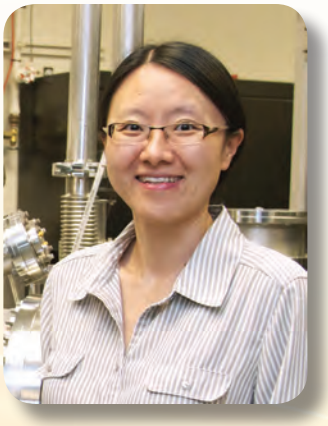
Edward Teller Award

The American Nuclear Society recognized Livermore's Jim Hammer as one of two recipients of the 2013 Edward Teller Award. Hammer is co-inventor of the fast-ignition approach to nuclear fusion energy. The Edward Teller Award recognizes pioneering research and leadership in the use of laser and ion-particle beams to produce unique, high-temperature and high-density matter for scientific research and for controlled thermonuclear fusion.

Secretary of Energy Award

Steve Homann received a Secretary of Energy Achievement Award. He served as senior science adviser for radiological contingency planning for NASA's Mars Science Laboratory Multi-Mission Radioisotope Thermal Generator team. Ahead of the launch of the Curiosity rover, which was powered by a "nuclear battery," Homann led a team that deployed environmental monitors to prepare in case of a radiological event. The monitor network was linked via satellite to LLNL's National Atmospheric Release Advisory Center, which was ready to provide emergency assessments if such an event were to occur.

DOE Early Career Award



Yuan Ping received a DOE Office of Science Early Career Research Program Award in recognition of her work on providing high-quality data on critical energy transport properties of high-energy-density matter.

NATO Award

Phil Pagoria received the 2013 NATO Munitions Safety Award for Technical Achievement in recognition of his discovery and development of the energetic molecule LLM-105, which has potential applications in enhancing the safety of nuclear and conventional weapons. The U.S. Defense Department's Under Secretary for Acquisition, Technology, and Logistics nominated Pagoria for the award.

Award for Contribution to Intelligence Report

As part of a multiagency team tasked with contributing to a Special National Intelligence Estimate (SNIE), Chris Carson received an Intelligence Integration Award from the Office of the Director of National Intelligence. Carson and the entire team were recognized for "demonstrated professional integrity, enthusiasm, and dedication to producing a SNIE on a sensitive [weapons of mass destruction] topic, demonstrating deep substantive knowledge, great sensitivity to alternative analysis, and the highest standards of analytical tradecraft." The award noted that the SNIE has had "a direct impact on foreign policy and national security."

New Mineral Named

A new garnet mineral ($Ca_3Ti_2SiAl_2O_{12}$) discovered in a refractory inclusion in the Allende meteorite has been named "hutcheonite" in honor of the Lab's Ian Hutcheon, who has made numerous contributions to the study of meteorites and what they can tell us about the evolution of the early solar system. The new name was formally announced at the 76th Annual Meeting of the Meteoritical Society, held in the summer of 2013.

NASA Group Achievement Award

Regina Soufli and her team at LLNL were awarded the 2012 NASA Group Achievement Award for "outstanding designing, building, and operating of the science investigations" of the Solar Dynamics Observatory, which from its orbit around the Earth, studies the Sun's interior and atmosphere.

Cybersecurity Awards

A team of LLNL employees won first place in Tracer FIRE 5, an NNSA-wide cybersecurity competition that brings together teams from national laboratories and the private sector for a three-day, around-the-clock trial. The Laboratory also won a 2012 U.S. National Cybersecurity Innovation Award for a strategy by which multiple DOE laboratories and sites improved their defense against persistent threats through the real-time sharing of reputation data in a master block list.

Inaugural Climate Award

Climate scientist Stephen Klein was one of the inaugural recipients of the American Geophysical Union's Ascent Award "for elucidating the role of clouds in climate change and the fidelity with which climate models simulate clouds."

Ph.D. and Postdoctoral Awards

Frederico Fiuza (shown), a Lawrence fellow at LLNL, was one of three recipients of the Ph.D. Research Award from the Plasma Physics Division of the European Physical Society. The Ph.D. thesis of Michael Kruse, a University of Arizona graduate student who spent three summers studying at LLNL, was chosen for publication in the *Springer Theses* series of publications.

Fellows

Five Laboratory scientists were honored as fellows of professional societies. Andris Dimits, John Moody, and Pravesh Patel were elected fellows of the American Physical Society. Chris Keane and Jane Long were named fellows of the American Association for the Advancement of Science.

First Place in Homeland Security Awards

A Livermore technology—the first plastic material capable of efficiently distinguishing neutrons from gamma rays—won first place in the "best nuclear/radiation detection" category of *Government Security News* magazine's fourth annual Homeland Security Awards. The low-cost material could be cost-effectively formed into large sheets covering far larger areas than is possible with current technologies at ports, stadiums, and other large facilities.

IEEE Senior Member

Physicist Mark Rowland was named a senior member of the Institute of Electrical and Electronics Engineers. Rowland has worked in radiation detection for much of his career at LLNL and led teams that developed two instruments that have been commercialized to inspect cargo. One instrument—the Detective—was sent to Japan following the Fukushima nuclear incident to calibrate aerial measurement systems.

Supercomputing Editor's Choice Award

At Supercomputing Conference 2012 (SC12), the Laboratory's Michel McCoy (right in photo) was officially presented by HPCwire publisher Tom Tabor with the Editor's Choice Award that HPCwire gave to Livermore's Sequoia supercomputer in the "top supercomputing achievement" category of its 2012 Readers' and Editor's Choice Awards.

LLNS Organization and Annual Costs

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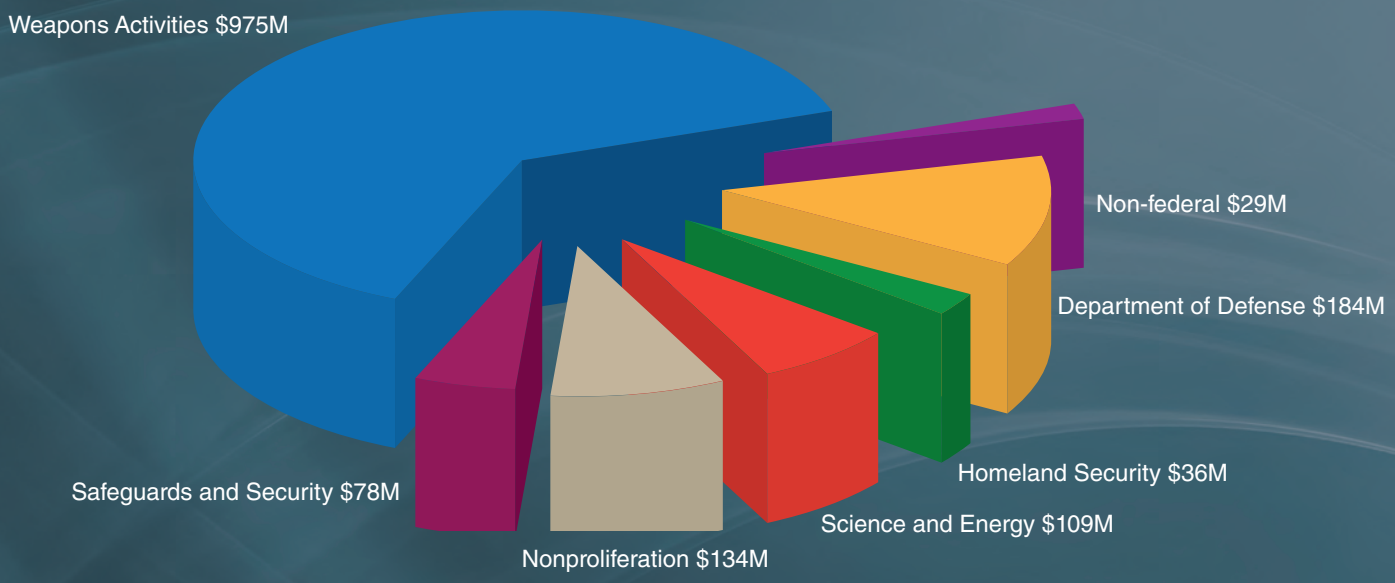
LLNS Board of Governors Chairman Norman Pattiz (right) and Vice Chairman Craig Albert (left) join acting Laboratory Director Bret Knapp at a joint meeting of the LLNS and Los Alamos National Security, LLC (LANS), boards. The two boards work to better integrate activities and make both laboratories and the NNSA enterprise more effective and efficient.

LLNL FY2013 Actual Costs: $1.55 billion



Lawrence Livermore National Security

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Board of Governors Committees
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Computation
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Physical and Life Sciences

Missions and Programs
Global Security | Weapons and Complex Integration | NIF and Photon Science

Operations and Business

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